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NEW METHOD OF DETECTING FM SIGNALS

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Radio amateurs building FM receivers often run into difficulties in tuning the frequency detector.

Recently, a new phase detector circuit suitable for detection of FM signals has been suggested. This circuit, giving good-quality operation, is simple to set up and tune.

Numerous tests have shown that a 6L7 tube operates very well in this circuit. We suggest that the 6A10 (6SA7) and 6A8 tubes will operate as well.

The circuit can be employed in both superheterodyne and straight receivers where the use of a conventional discriminator as an FM signal detector is very difficult.

The suggested circuit in simplified form is shown in Figure 1 [figures referred to are appended]. Here the FM signal voltage is applied to the third grid of the heptode. The coil L_c and capacitor C_c form the load circuit for the last stage of rf or i-f amplification.

If a small positive voltage (30-50 v) is applied to the screen grids, the tube will have a characteristic with a short left portion (-1.5 to 3 v) and at higher signal levels there will be a natural limit to plate current.

The first grid of the heptode is connected to the circuit $L_k C_k$ which is tuned to the average band-pass frequency of the rf amplifier (or i-f amplifier): i.e., to the frequency of the unmodulated signal.

Hereinafter we shall refer to this circuit as the "square-law detector."

There must be no parasitic coupling between the first and third grid circuits. It is better to place them on opposite sides of the chassis. Oscillations in the square-law detector are excited due to the effect of the electron stream controlled by the third (signal) grid on the first grid.

Let us examine the operating principles of this circuit.

As we know, the first and third grids have practically the same effect on the plate current of a mixer tube in the left portion of the characteristic. Let us assume that a voltage of the same frequency (synchronized excitation) is applied to both grids. Let us see what changes take place in the form of the oscillations and the coverage value of the plate current when the relative phase of the voltages in both grids varies. For the sake of simplicity, let us assume that a voltage is applied to the grids which is rectangular in form and of such an amplitude that, in the negative half cycle on one of the control grids, the plate current cuts off independently of the sign of the voltage on the second grid.

We can readily obtain such conditions with a 6L7-type heptode. The plate-current pulse form (Figure 2) will strongly depend on the relative phase shift between the grid voltages. It is obvious that the plate current can flow only during that portion of the cycle when the voltages on both are positive in sign. The wave form of the plate current will resemble the exciting voltage only when both voltages are completely in phase. With a 90° negative shift of voltages, the plate current pulses will be twice as narrow as when the voltages are in phase.

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When there is a 180° voltage phase shift (antiphase excitation), the plate current generally stops flowing. Hence the mean value of the plate current can be controlled through shifting the relative phase of voltages on the grids.

An analogous condition is obtained if the control grids are fed by voltages which are not rectangular but sinusoidal in form. If the voltages on the grids are insufficient to stop the plate current entirely, its value will still be changed within certain limits.

Returning to the circuit shown in Figure 1, if the third grid is supplied an alternating voltage of the frequency to which the square-law detector is tuned, the voltage induced in this circuit will have a phase lag of 90° behind the excitation voltage, and some average value will be established for the plate current I_0 (Figure 3).

If the excitation frequency is increased, the relative phase shift will also increase, resulting in a reduction of the plate current. At an excitation frequency lower than the resonance frequency of the square-law detector, the relative voltage phase shift will be less than 90° , and the plate current will be increased. It is obvious that if FM oscillations are applied to the third grid, variations in the average value of the plate current will correspond to a modulating signal, and we can take off oscillations from the plate load of the tube.

The characteristic of this detector is quite linear within the limits of the pass band of the square-law detector. Hence it follows that the circuit must have enough attenuation so that, in detuning by the deviation value, suppression of the resonance characteristic will not be more than 0.7 of the resonance value.

An increase in attenuation of the square-law detector tends to decrease the transconductance of the detector characteristic. In practice, a pass band of approximately 300 kc is adequate for our assumed 75-kc deviation.

A straight receiver with a 300-kc pass band requires a circuit with a Q of about 200. On ultrashort waves this circuit is not feasible when coupling with the tube is direct because of the shunting action of the tube's input resistance. But even in some extra bands the transconductance characteristic will be sufficient.

In certain cases, to obtain the required pass band it is necessary to shunt the circuit through a resistance of 20,000-25,000 ohms.

To improve the operation of the circuit, the input capacitance of the square-law detector must be selected as a minimum.

The permissible Q for the circuit may be calculated by the formula

$$Q = \frac{f_{N.ZV.}}{0.3} \quad (1)$$

where $f_{N.ZV.}$ is the carrier frequency of the audio channel in Mc.

The equivalent resonance resistance for the circuit (needed for selecting the shunt) can be calculated by formula 2, if the circuit capacitance is even approximately known:

$$R_{oe} = \frac{Q \cdot 10^3}{2\pi f_{N.ZV.} C_k} \quad (2)$$

where R_{oe} is the equivalent resistance of the circuit in thousands of ohms; $f_{N.ZV.}$ is calculated in Mc; and C_k is the capacitance of the circuit in $\mu\mu$ fd.

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Figure 4 shows the actual circuit for this detector. The capacitor C_a , which shunts out the plate load, not only blocks the high frequencies, but also suppresses higher modulation frequencies. This is necessary because of the rise of the frequency response of an FM transmitter modulator in this region.

The magnitude of the af voltage taken from the detector plate load depends on the operating conditions of the tube, primarily on the screen-grid voltage, which, in its turn, must be selected in relation to the excitation voltage on the receiving circuit. The higher this voltage, the higher will be the screen-grid voltage at which we shall obtain a limiting effect.

It must not be forgotten that cathode, screen-grid, and plate currents contain both af and rf components and that, therefore, power-supply and automatic bias circuits must be blocked by high capacitances, which are shunted by noninductive capacitors.

The phase detector is easily tuned by ear from the operation of a transmitter. If there is an rf oscillator, the square-law detector can be tuned by a milliammeter connected to the plate circuit of the detector. The signal from a 2- to 3-v oscillator is fed to the third detector grid. By changing the square-law detector tuning, from milliammeter readings one can obtain a curve like that in Figure 3 (in this case the resonance frequency, not the excitation frequency, varies), and adjustment can be made to correspond to the average (between greatest and least) deviation of the milliammeter.

An rf pentode can be used in this circuit. In this case, the receiving circuit is connected to the first grid, and the square-law detector to the pentode grid. To increase the square-law excitation, a 500- to 1,000-ohm resistance is connected between the plate and the load which is shunted by a capacitor. The square-law detector is excited through the plate-suppressor grid interelectrode capacitance. The coupling can be improved by connecting a 3- to 5- μfd capacitor between the plate and the pentode grid.

It should be noted that, if a pentode is used, the additional resistance in the plate will attenuate the square-law detector to some extent, and a shunt may not be required.

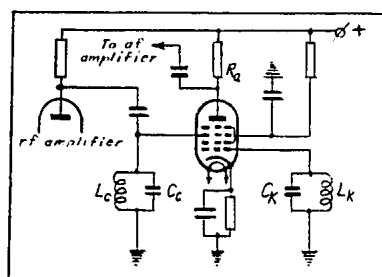


Figure 1

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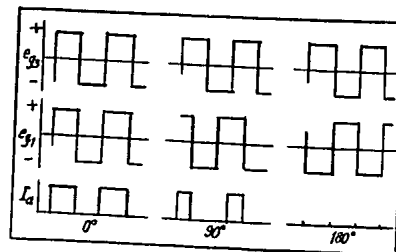


Figure 2

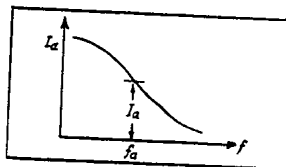


Figure 3

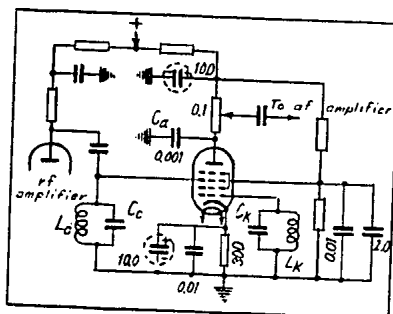


Figure 4

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